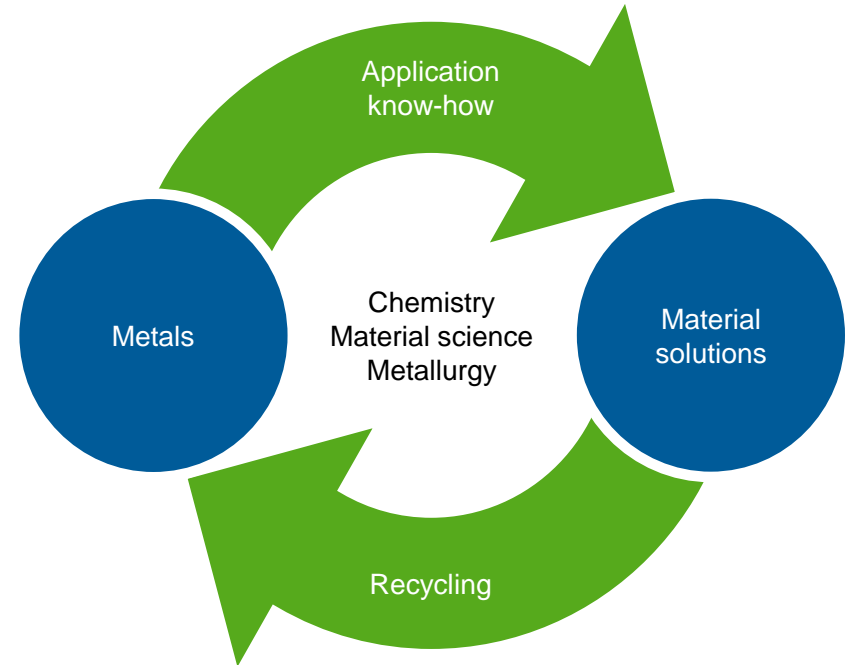


Industrial scale EOL (X)EV Battery Recycling –
an existing solution in a global network

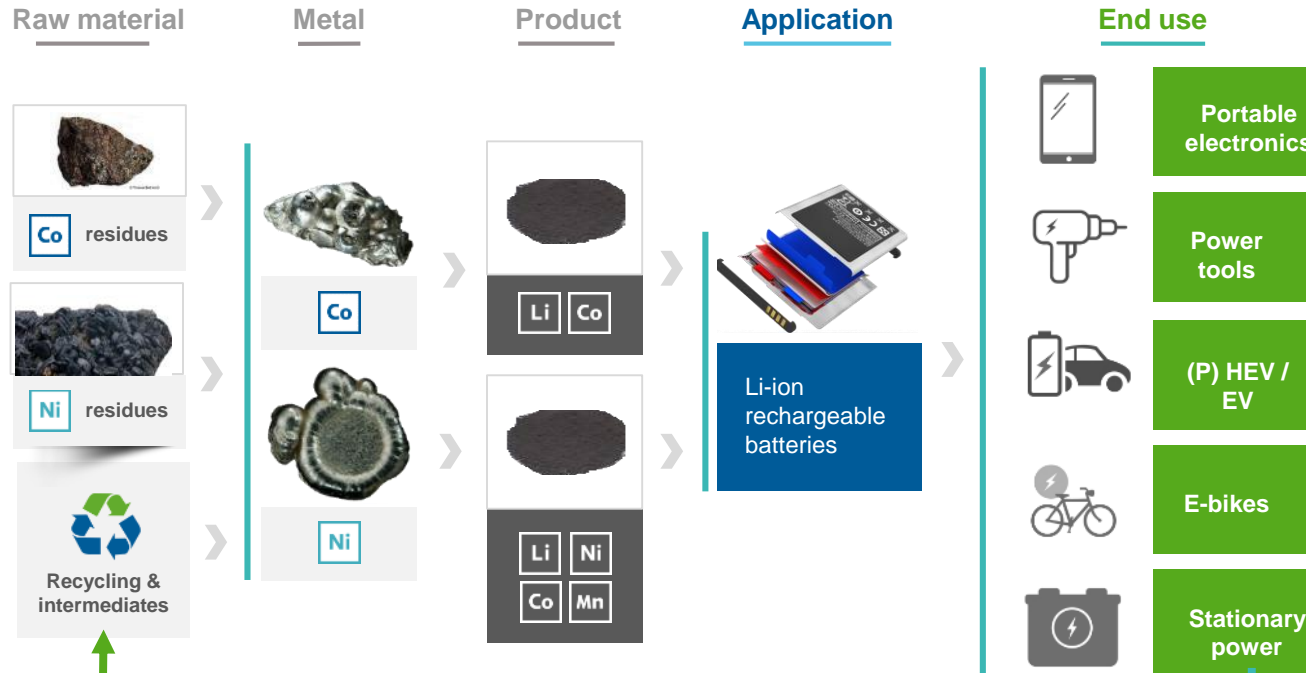
Umicore business approach

- We transform metals into hi-tech materials
- We use application know-how to create tailor-made solutions in close collaboration with our customers
- We close the loop and secure supply by recycling production scrap and end-of-life materials
- We aim to minimize the environmental impact and be the best employer and neighbour



Unique integration in the battery value chain

guaranteeing high speed to market, supply security and responsiveness to customer needs



Umicore offers a **closed materials loop for Li-ion batteries**: The innovative recycling process enables a **cost efficient and environmentally sound** battery recycling with **high recovery rates and minimal waste**.

Fundamentals of effective Recycling

Input

Flexibility for complex materials



Pyrometallurgy
Hydrometallurgy
Mechanical processing



Recovery of > 20 metals

Output

Maximize value creation



Base metals



Minor metals

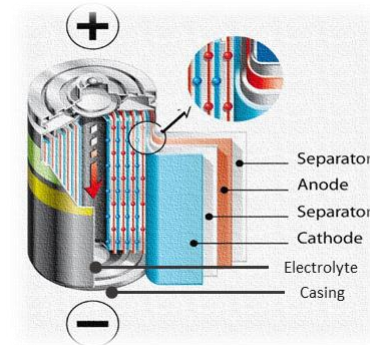


Precious metals

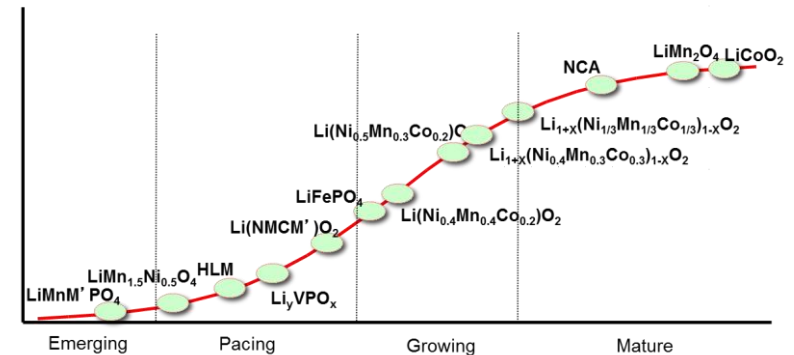
Treating all kinds of Li-ion batteries

Li-ion battery = **complex** mix of materials containing metals, organics, halogens:

- Strong **variation in cathode chemistries** with more variation to come
- Umicore has **knowledge on battery chemistry evolution** through its Rechargeable Battery Materials division



Umicore's UHT-process is designed to handle this complexity and variability



Innovative technology for metal recovery

1887



Continuous innovation and investments for recycling efficiency and QEHS improvement.

More than € 600 million of investments over the past 20 years and ongoing ...

2017



Experience in Industrial Scale Processing

Precious metal recycling
 industrial scale
 >1000 t / day
 >350.000 t / year



Delivers...

Battery recycling
 industrial pilot scale

7000 t / year



...experience and know how to grow from
 current to future high volume scale

Variable feed size

Flexible on Size

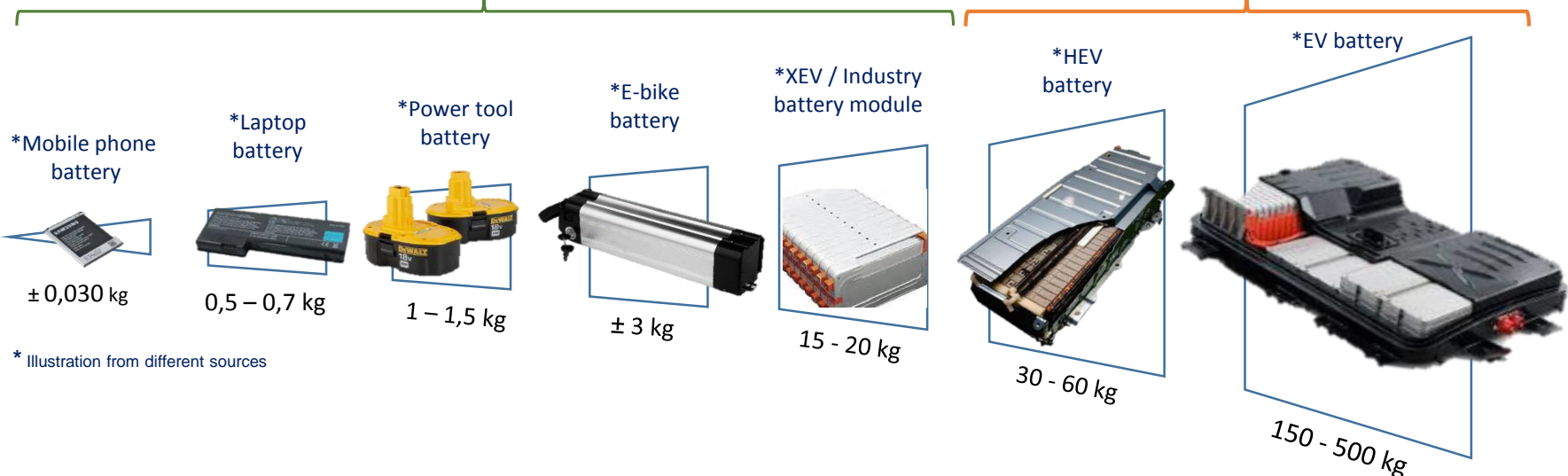
- Medium sizes → directly to furnace
- Larger sizes after (partial) dismantling

No pre-treatment necessary

= direct feed to the furnace

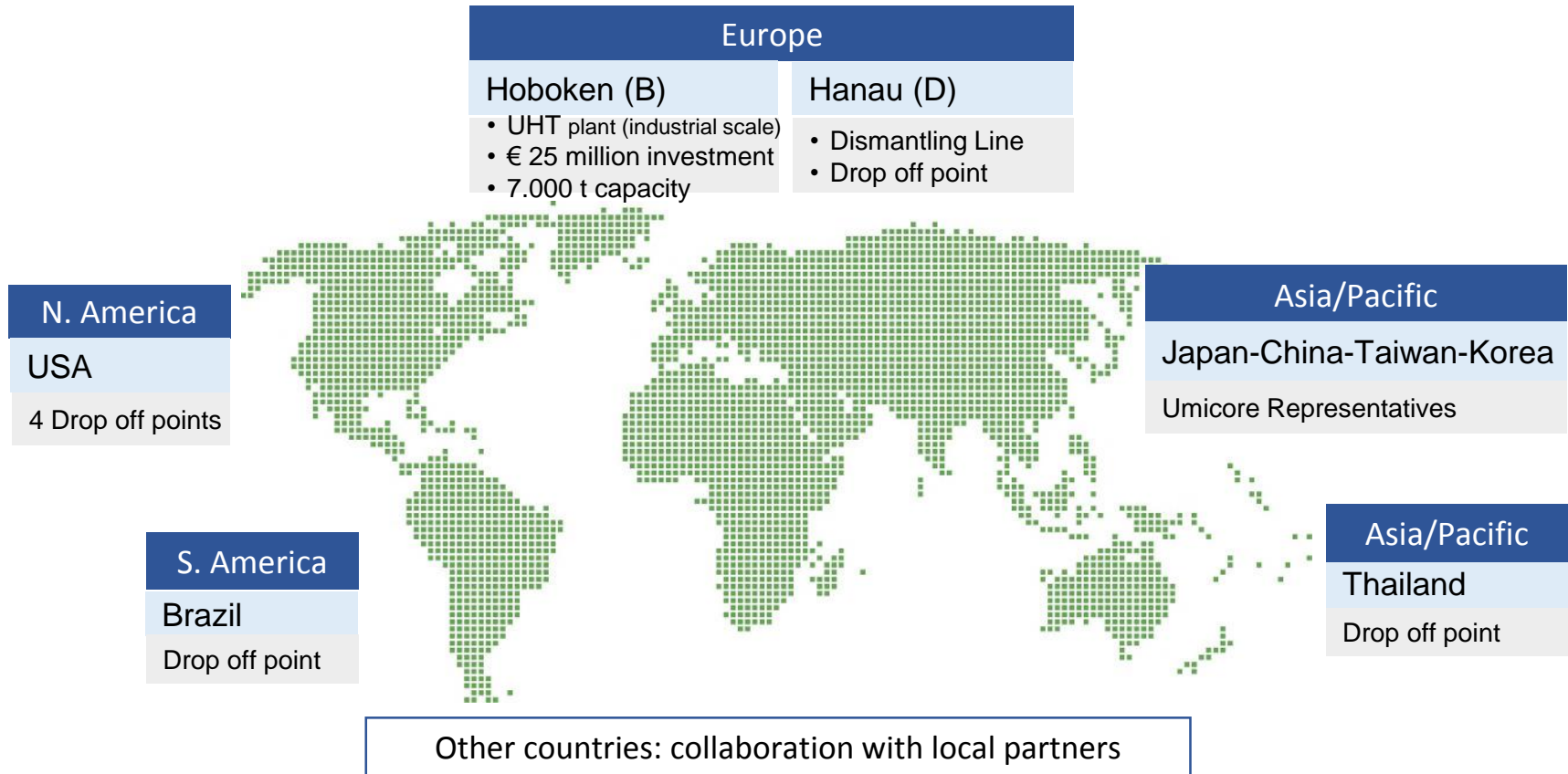
Pre-treatment necessary

= dismantling to module/cell level



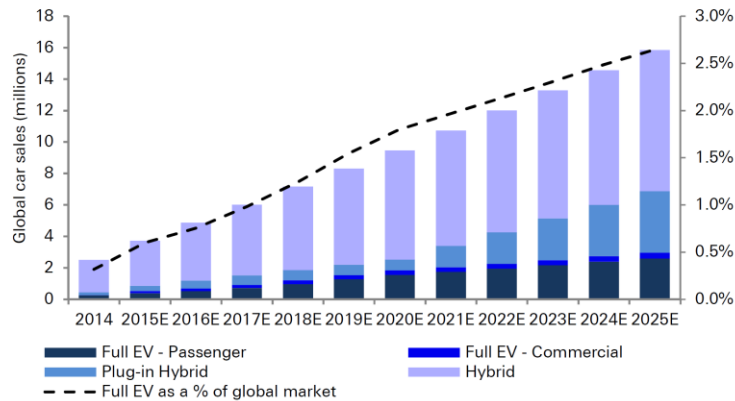
* Illustration from different sources

Drop-off points as customer oriented service network



Growing with the market

Figure 32: Deutsche Bank global EV sales estimates



Source: Deutsche Bank estimates, IHS

Governments' xEV targets by 2020:

14 countries have announced quantitative EV stock objectives, aspiring to bring **13 million EVs** on the road **by 2020**:

- Germany: 1 million cumulative sales
- UK: 1.5 million cumulative sales
- France: 2 million cumulative sales
- China: 5 million cumulative sales
- Etc...

Source: Global EV outlook 2016 - OECD/IEA 2016



several 100,000 metric tons in need for recycling in the years thereafter

When?
How?

Uncertain, depends on actual sales xEV, battery designs, lifetime batteries, potential 2nd life, ...
Efficiency and cost of recycling are driven by volume

Recycling technology → UHT

Capacity:

7,000 t/y installed

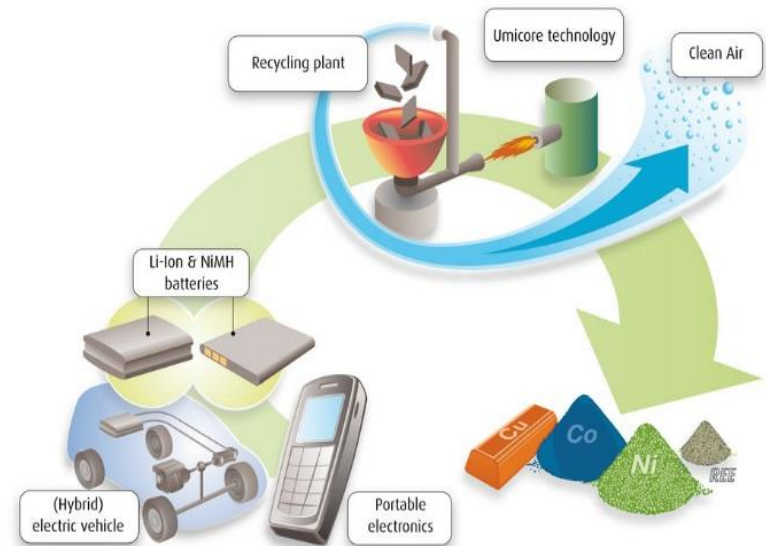
- ± 250 mio mobile phone batteries or
- ± 200,000 HEV's or
- ± 35,000 EV's

Recycling efficiency > 50%:

- Alloy: Cu – Co – Ni
- Slag : for Li-Ion: used in construction (potential recovery Li)
for NiMH: rare earth concentrate (REE)
- Flue dust: controlled separation of F

Eco-efficient:

- Close-to-zero waste
- Advanced gas cleaning
- Energy of battery used to obtain high temperature (incl. the caloric energy (electrolyte, plastic, metal))



Umicore Battery Recycling Scheme

For discussion: Aspects, Conclusions and Perspective

Battery recycling efficiency is specified as an EU standard and to ensure recycling quality to keep sustainability high and environmental impacts low:

- Battery recycling processes are only qualified if a recycling efficiency > 50% will be reached for all kind of batteries – Reference: EU Battery Directive

Effective Battery Recycling (economic and ecological) requesting technological flexibility because of...

- High dynamic of battery chemistry and high variety of composition
- High variety of battery pack and module design
- Different conditions of batteries (esp. damaged) require flexibility in handling and (pre)treatment to ensure safety → exchange of info / data along the waste & recycling chain is essential

Furthermore effective Battery Recycling (economic and ecological) in a circular economy needs:

- To be well understood as a final part of a (complex) chain with strong interfaces which has to be managed
- Strong cooperation between involved partners with an interdisciplinary approach
- Exchange of information as important part of a safety concept (e. g. BMS data → battery history)
- Well established collection schemes – well prepared for safe handling at high volume streams
- Well established logistic solutions – allowing management of high volume streams
- To bring back resource-critical and valuable material (metals)
- Reuse and 2nd life solutions / concepts
- Clarification and aligning of waste classification / waste code on EU level → “individual” view doesn’t help



Thank you